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James J. (Jong Hyuk) Park
Young-Sik Jeong
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Hsing-Chung Chen *Editors*

Embedded and Multimedia Computing Technology and Service

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Message from the EMC 2012 General Chairs

On behalf of the organizing committees, it is our pleasure to welcome you to the 7th International Conference on Embedded and Multimedia Computing (EMC-12), will be held in Gwangju, Korea on September 6–8, 2012.

The EMC-12 is the next event, in a series of highly successful International Conference on Embedded and Multimedia Computing, previously held as EMC 2011 (China, Aug. 2011), EMC 2010 (Philippines, Aug. 2010), EM-Com 2009 (Korea, Dec. 2009), UMC-08 (Australia, Oct. 2008), ESO-08 (China, Dec. 2008), UMS-08 (Korea, April, 2008), UMS-07 (Singapore, Jan. 2007), ESO-07 (Taiwan, Dec. 2007), ESO-06 (Korea, Aug. 2006).

This year the value, breadth, and depth of the EMC conference continues to strengthen and grow in importance for both the academic and industrial communities. This strength is evidenced this year by having the highest number of submissions made to the conference, which has resulted in our selective program. In addition, the publishing of special issues from six famous journals (*The Journal of Supercomputing, Cluster Computing, Multimedia Tools and Applications, Journal of Systems Architecture, INFORMATION, and International Journal of Sensor Networks*) make this conference stronger.

We sincerely thank all of our chairs and committee members, as listed in the following pages. Without their hard work, the success of EMC 2012 would not have been possible. We hope you find EMC 2012 enjoyable and please let us know if you have any suggestions for improvement.

Young-Sik Jeong, Wonkwang University, Korea
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EMC 2012 General Chairs

Message from the EMC 2012 Program Chairs

Welcome to the 7th International Conference on Embedded and Multimedia Computing (EMC-12), will be held in Gwangju, Korea on September 6–8, 2012.

EMC-12 will be the most comprehensive conference focused on the various aspects of advances in Embedded and Multimedia (EM) Computing. EMC-12 will provide an opportunity for academic and industry professionals to discuss the latest issues and progress in the area of EM. In addition, the conference will publish high quality papers which are closely related to the various theories and practical applications in EM. Furthermore, we expect that the conference and its publications will be a trigger for further related research and technology improvements in this important subject.

For EMC 2012, we received a total of 113 paper submissions from more than 20 countries. Out of these, after a rigorous peer review process, we accepted 29 articles for the EMC 2012 proceedings, published by the Springer. All submitted papers have undergone blind reviews by at least three reviewers from the technical program committee, which consists of leading researchers around the globe. Without their hard work, achieving such a high-quality proceedings would not have been possible. We take this opportunity to thank them for their great support and cooperation.

We would like to sincerely thank the following speakers who kindly accepted our invitations, and, in this way, helped to meet the objectives of the conference:

- Yang Xiao, The University of Alabama, USA

Finally, we would like to thank all of you for your participation in our conference, and also thank all the authors, reviewers, and organizing committee members.

Thank you and enjoy the conference!

Sang Oh Park, KISTI, Korea
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Bin Xiao, Hong Kong Polytechnic University, Hong Kong
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Image Dynamic-Range Enhancement Based on Human Visual Adaption Mechanism

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Abstract. In this paper, an image dynamic-range enhancement method is proposed based on the computational model from human visual adaption mechanism. The method can be used in the image display with weak or strong background luminance and improve the intelligent video processing efficiency of current smart cameras. Na^+-Ca^{2+} model and psychophysical thresholds model are analyzed respectively, then realized by proposed algorithms. Real human visual process of dark adaption is simulated. More, comparative simulations of image display dynamic-range enhancement for both dark and light adaption are carried out. The PSNR performance and detail in figures are improved simultaneously.

Keywords: visual perception, visual adaption, image dynamic-range, image display.

1 Introduction

Biological visual systems(human eyes especially) enjoy the merit of automatically adapting to all levels of brightness(despite extreme darkness) without much sacrifice of clarity. Such merit called visual adaption is unfortunately absent from current smart cameras. In order to improve the efficiency of intelligent video processing through increasing cameras' adaptation to background luminance(darkness especially), we conducted a biomimetic simulation. Knowledge from anatomy, psychophysics, and neuroscience is employed.

During the past 30 years, much has been achieved about visual adaptation thanks to illustrative mechanisms from different field despite the bulking physiological complexity. The structure of retina[3][4][5] as well as the complex mechanism explaining the suitability of biological eyes under changing brightness[6] are revealed.

In this paper, a method of biomimetic visual adaption based on visual characteristics is detailed, the choice when dealing with engineering approximation is explained and the underlying relationship illustrated. Also, an algorithm is put forward for systematic processing. Respectively, Part II focuses on the achievements of research on human visual system, mainly about visual adaption, Part III

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progressively explains the visual adaption based algorithms, the result of simulation using the mentioned algorithms is further illustrated in Part IV and finally, a conclusion together with the prospect appears in Part V.

2 Background

2.1 Photosensitive Characteristics

Human visual systems can work in a large range of luminance levels more than $10^{10}:1$ (candelas/ m^2), compared with $10^3:1$ of cameras. A question remains that the response range of visual systems is limited to approximately as low as 100:1. A crucial mechanism of *visual adaption* is developed by the visual systems. Fig.1 shows the function of the cones in visual adaption, the reaction inside the cones is the key mechanism contributing to visual adaption which will be discussed in Part 2.2.

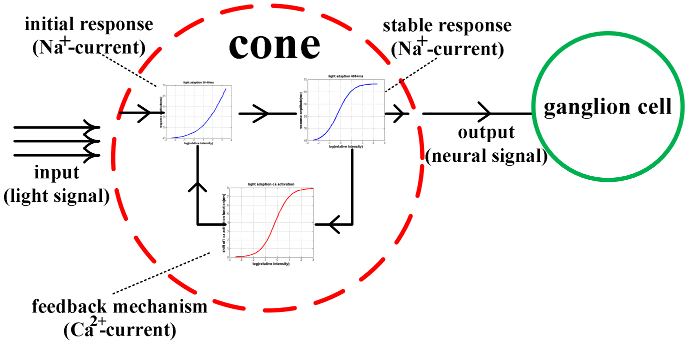

Fig. 1. The reaction inside the cones in visual adaption

2.2 Visual Adaption

To recuperate the sensitivity to a large range of input with a limited response range, the photoreceptors and the ganglion cells employ a strategy called *visual adaption*: the response to input light is dependent on the average intensity of luminance on the retina. There are generally two important types of visual adaption: light adaption and dark adaption. Light adaption means vision in bright light with light-adapted eyes and dark adaption means vision in dim light with dark-adapted eyes.

One crucial improvement in the research of visual adaption these years is the success of molecular level description. Compared with the once over-whelming but now proved insignificant hypothesis that the visual adaption is determined by rhodopsin, molecular level description reveals the complex reactions happening in photoreceptors and adequately explains the features of visual adaption in short periods. In this paper, we describe a model based on this new improvement rather than the rhodopsin hypothesis used in previous works (As in [1][2]).

In visual adaption described in molecular level, a crucial part is called *the calcium feedback mechanism*. After the optical signals are transduced into the neural signals (the Na$^+$-current), the membrane potential of the photoreceptors is decreased by the Na$^+$-current flowing out. During this process, the Ca^{2+}-current enters the cell through cation channels and is expelled from the cell by an electrogenic calcium-sodium exchanger. That is to say, the Ca^{2+}-current can function as feedback to control the descending speed of the membrane potential.

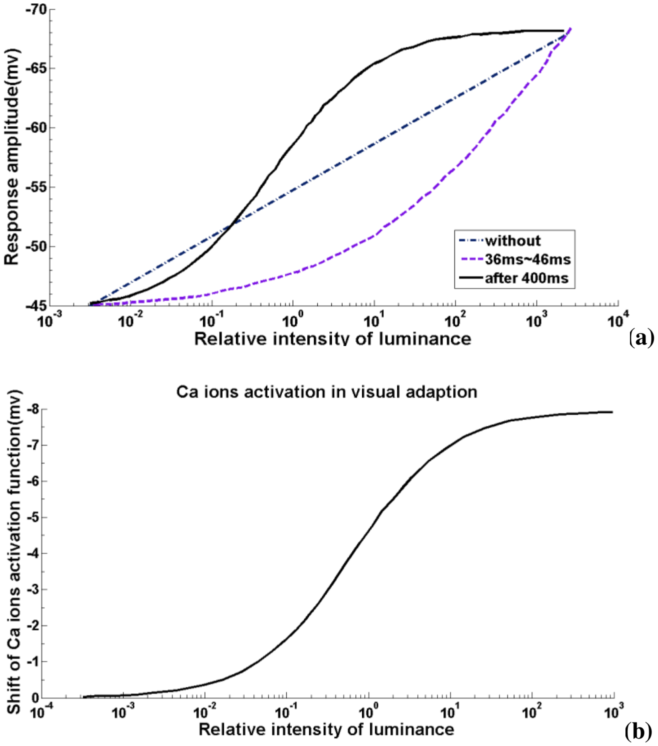

Fig. 2. **(a)** The curve of hypothetical relationship without light adaption, the curve of response amplitude in 36-46ms (transient state) after light onset and the curve of response amplitude 400ms (stable state) after light onset **(b)** Shift of the Ca^{2+}-current activation function as a feedback of the relative stimulus intensity during light adaption Redrawn from Kraaij & Spekreijse. [3]

Research on the retina of goldfish[3], cats[4] and human[5], expose a general existence of a same pattern of visual adaption. The only difference is the response time which, obviously, could be chosen in algorithms.

Fig.2 shows the response amplitude of visual systems of goldfish to sudden flash in darkness. In Fig.2 (a) the hypothesized relation without visual adaption between response and stimuli according to Weber's law is given. In the curve of response amplitude in 36-46ms (transient state), the increasing speed of the response amplitude is larger as luminance increasing. Also, the response curve after 400ms (stable stage) shows that the system expands the output range in medium luminance. Ca^{2+}-current functions as feedback to adjust the neural signal (Na$^+$-current) intensity from initial stage to stable stage. Fig.2 (b) reveals the shift of the Ca^{2+}-current activation during visual adaption.

From the aspect of the changes of membrane potential (as in Figure.2), the process of visual adaption could be described as the shifting among a set of curves of response-stimulus relationship. That is to say, the stable relationships between luminance intensities and response of the photoreceptors are dependent on the environmental luminance.

2.3 Psychophysical Thresholds

As there is not a satisfactory theoretic model that could completely match the complete time course of visual adaption. A psychophysical description of the time course of visual adaption is introduced from psychophysical visual thresholds. Visual threshold is a traditional measurement of the visual adaption process. The process of the experiments, in brief, is that the subject's distinction ability to different luminance intensities is measured at different time points in the procedure of visual adaption and the average minimal luminance differences are named *visual thresholds*[6].

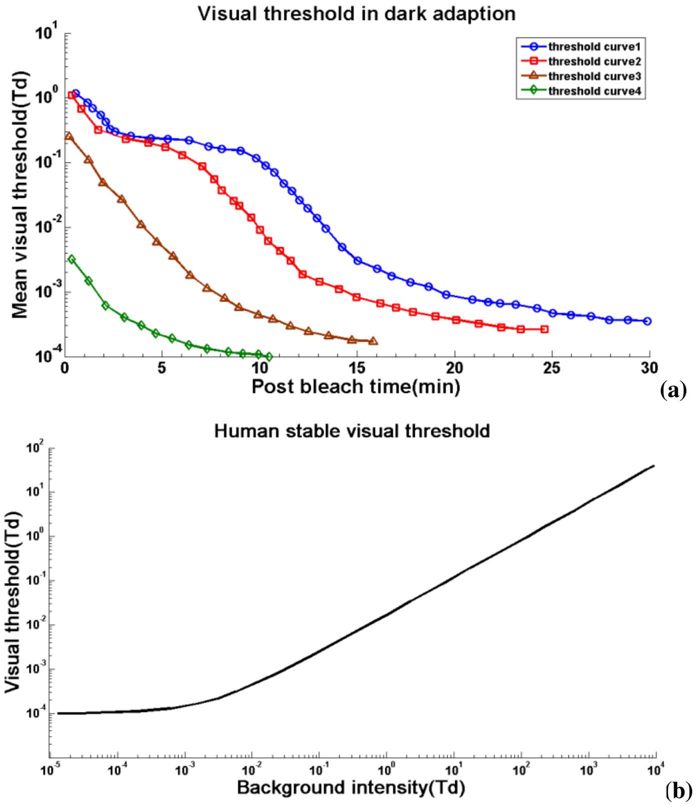

Fig. 3. **(a)** Recovery time course of visual threshold from complete darkness to different luminance levels, the luminance levels decreases form curve 1 to curve 4. **(b)** Stable visual thresholds of human at different luminance levels. Redrawn from Ruseckaite [6].

Fig.3 (a) shows an example of human visual threshold changes in dark adaption. As the initial luminance level and the final luminance level change, the time course of the recovery of the visual threshold also differs. A model used in biology describing the time course of dark adaption is to treat the curves shown in Fig.3 (a) as three separate stages controlled by different parameters. At any given background luminance intensity, the visual system has a minimal visual threshold in stable stages as in Fig.3 (b). As for light adaption, the visual threshold along the time course changes quickly and the algorithm for it is similar to dark adaption.

3 Human Visual Adaption Based Image Enhancement

3.1 Mathematic Description of the Visual Adaption

Crawford transformation is a method to convert the psychophysical perception during adaption into equivalent background intensities from weber's law[7]. The equation to convert the visual thresholds is (1) in which s_D is the initial visual threshold in stable luminance (as in Fig.3(b)), s is the current threshold during adaption, I_s and I_{equiv} represent intensities and correspond to s and s_D respectively, n_s is a constant dependent on visual systems representing the response amplitude to the input intensity:

$$I_{equiv} = I_s \cdot \left(\frac{s}{s_D} - 1\right)^{1/n_s} \tag{1}$$

The intensity-response curves are described by (2). Corresponding to calcium feedback mechanism introduced in Part 2.2, σ reflects the luminance range that the photoreceptors is sensitive to, n reflects the degree of calcium feedback intensities.

$$f(n, \sigma) = \frac{I_{equiv}^{n}}{I_{equiv}^{n} + \sigma^{n}} \tag{2}$$

As the threshold curve 1 showed in Fig.3(a), the curve representing the visual threshold can be divided into three parts contributed by S1, S2 and S3 components respectively. S1 component stage only appears when the change of light intensities is overly intense, S2 and S3 components can be regarded as straight lines in (3).[6]

$$I_{equiv}(t) = I_{S2}(0) \cdot 10^{\Psi_{s2}t} + I_{S3}(0) \cdot 10^{\Psi_{s3}t} \tag{3}$$

The coefficients of Ψ_{S2} and Ψ_{S3} could be calculated from the psychophysical experiments, in which Ψ_{s2} and Ψ_{s3} are the slopes of the S2 and S3 components in log_{10} units min^{-1} while $I_{S2}(0)$ and $I_{S3}(0)$ are the initial magnitudes of the S2 and S3 components in the recovering of visual threshold. According to (1) and (3), the equation describing the decaying of visual threshold is as (4).

$$s(t) = s_2(0) \cdot 10^{\varphi_{s2}t} + s_3(0) \cdot 10^{\varphi_{s3}t} + s_D \tag{4}$$

A step of visual threshold can be regarded as a unit of gray level in digital image. The luminance intensities included in a certain step of visual threshold share the same intensity of response. As the dark-adapted visual threshold is about 10^{-4}Td (Td measures retinal illumination, computed by $\mathrm{T} = \mathrm{L} \cdot \mathrm{P}$ in which L is the luminance and

P is pupil area), then a 10^{-1}Td range of luminance has 10^3 steps of perceptible luminance intensities.

Suppose the maximal level of visual response is R in (5). The number of the response steps is determined by(β equals 10^3 in most cases in (5)):

$$\text{steps} = \frac{R}{s} = \frac{\beta \cdot s_D}{s} \tag{5}$$

Then the complete curve is:

$$\mathrm{f(s)} = \frac{R}{s} \cdot \frac{I_{equiv}^n}{I_{equiv}^n + \sigma^n} = \frac{\beta \cdot s_D}{s_2(0) \cdot 10^{\Psi_{s2} t} + s_3(0) \cdot 10^{\Psi_{s3} t} + s_D} \cdot \frac{I_S \cdot (\frac{s}{s_D} - 1)^{n/n_S}}{I_S \cdot \left(\frac{s}{s_D} - 1\right)^{n/n_S} + \sigma^n} \tag{6}$$

3.2 Algorithms for Simulating Visual Adaption

The difference between visual systems and current camera systems is the information of luminance and color in a digital image is usually recorded in certain storage space. This is different from the visual system in which the storage space could be considered to change from 10^{10} before processing to 10^4 after processing. Such difference determines that the algorithm to imitate visual adaption needs not severely compress other range of output. For a given image, the luminance distribution can be adjusted using Algorithm 1 to fit the response of human eyes. The coefficients of the adjustment are dependent on the average luminance of the input image.

Algorithm 1. Simulation intensities-response curves

```
Input: A matrix X(i, j) representing an image(8-bit color)
Input: the array of coefficients G[10,2] for $(n, \sigma)$
Output: A new matrix X'(i, j) representing the image processed
    calculate the average luminance L of the image
    if L < 8
        use G[1] as the coefficient for exponential luminance correction of matrix X
    else if L < 16
        use G[2] as the coefficient for exponential luminance correction of matrix X
    ……
    else if L < 248
        use G[9] as the coefficient for exponential luminance correction of matrix X
    else
        use G[10] as the coefficient for exponential luminance correction of matrix X
    end if
```

As the changes of pupil size during visual adaption are slower than photoreceptors, the strategy to simulate the time course of visual adaption we adopt is to dismiss the changes of pupil size which contribute less in visual adaption and to use the adapted visual threshold as the minimal unit of gray level. Using either results of psychophysical experiments or (3) with coefficients Ψ_{S2} and Ψ_{S3} we can add time parameter to actual simulations. Finally, the complete algorithm for time course of visual adaption is detailed in Algorithm 2.

Algorithm 2. Complete simulation of time course of visual adaption

```
Input: A matrix $X(i, j)$ representing an image(8-bit color)
Input: the array of time course $t[N]$, visual threshold $s[N]$, coefficients for intensity-response curves $G[N,2]$, stable visual threshold $s_D$.
Output: A new set of matrixes $X'(i, j, N)$ representing the process of visual adaption.
    calculate the average luminance $L$ of the image.
    calculate the response range $R[N]$ from $s[N]$ and $s_D$.
    for i = 1: N
        using $s[i]$ to adjust the luminance distribution of $X(i, j)$;
        using $R[N]$ to compress the response range of $X(i, j)$;
    end
```

Based on the algorithm, only a table of coefficients and some basic calculations are needed to be added to camera systems. This avoids the increase in the complexity of camera systems that is inevitable in other image processing techniques.

4 Experimental Results

4.1 The Simulation of Visual Adaption

The image processing capacity of proposed approaches was evaluated by a set of images taken during a day of a same scene (the covers of two books).These photos were taken in Beijing, China, 9/19/2011 with Canon EOS 550D. Each image has a dimension of 600×400 pixels.

A process of dark adaption with 30 minutes is showed in Fig.4(Corresponding to threshold curve1 in Fig.3(a)). The pictures at 10, 20 and 30 minutes correspond to adjusting results of S1, S2 and S3 components, respectively.

The results of simulating the intensity-response curves are shown in Fig.5. These images show the ultimate results of visual adaption in extreme dark and bright enviroments. Compared with the standard image taken in medium luminance, the images after adaption reveal more details hiden in the initial images.

The amelioration of images under extreme low and high luminance is much obvious as is showed in Fig.5, resulting from the adjustments from simulating the visual adaption effects under dark and bright luminance.

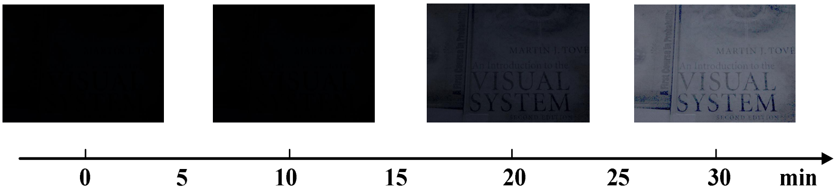

Fig. 4. A sample of dark adaption using Algorithms 2

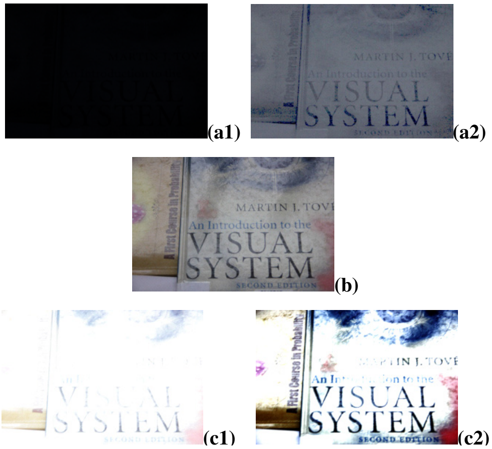

Fig. 5. Images processed using Algorithm.1, simulating the final effect of visual adaption in stable stages. Left column: initial images. Right column: processed images. (a) simulation to dark adaption effect,(a1):original image, (a2):processed image (b) standard image (c) simulation to light adaption effect, (c1):original image, (c2):processed image.

4.3 Quantification to the Results

The PSNR of the processed images to initial images is listed in Table.1. The PSNR is calculated to evaluate the effects of image processing and the degree of distortion. The processed images not only have larger PSNR to the standard image, but also can reveal more details as is showed in Fig.5.

Table 1. PSNR in Fig.5（8-bit image）

initial luminance:	**original image(a1 & c1) to standard image(b):**	**processed image(a2 & c2) to standard image(b):**
dark adaption:		
(a1) 2.4	6.10	16.55
light adaption		
(c1) 249.1	6.24	8.11

4.4 The Discussion of Applicable Range

The simulation of visual adaption can be used in many potential fields. The time course of visual adaption can provide imitation of the actual adaption for people with poor vision. The method in Algorithm.1 can be used to provide images with visual adaption features that are more amicable to human eyes.

5 Conclusion

We have presented two algorithms as an approach for simulating visual adaption. The algorithms come from imitation and simulation to the studies of neuroscience on visual systems as well as psychophysical experiments. The concepts of intensity-response curve and visual threshold are introduced from both biology and engineering utility. The time course of dark adaption is acquired using the algorithms discussed. Also, the final application effect of visual adaption is given.

Contrasted to original images, adjusted images are more comparable to the standard images taken under medium luminance. Naturally, distortion and luminance aberration are inevitably generated in the adjusting process. The coefficients in the experiments are chosen to best simulate the visual system and can be adjusted according to engineering practice for optimization.

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